21'st AIAA/IEEE Digital Avionics Systems Conference, Irvine, CA, October 28-31, 2002.

Functionalities, Displays, and Concept of Use for the Surface Management System

Stephen Atkins, NASA Ames Research Center, Moffett Field, CA
Christopher Brinton, Metron Aviation, Inc., Reston, VA
Deborah Walton, NASA Ames Research Center, Moffett Field, CA

Abstract

NASA Ames Research Center, in cooperation with the FAA, is developing the Surface Management System (SMS), a decision support tool that helps controllers and air carriers collaboratively manage the movements of aircraft on the surface of busy airports, thereby improving capacity, efficiency, and flexibility. This paper describes the Surface Management System, which is an element of the FAA's Free Flight Phase 2 program, and its concept of use. Detailed information about future departure demand on airport resources is not currently available in real-time to operational specialists at air traffic control (ATC) facilities and air carriers. SMS provides controllers, traffic managers, and air carrier decision-makers with accurate predictions of the future departure situation (e.g., queuing and delays for individual aircraft, and aggregate demand for each runway or other constrained resource), as well as advisories to help manage surface movements and departure operations. Two controller-in-the-loop simulations of SMS have been conducted in the Future Flight Central ATC tower simulator at NASA Ames Research Center, leading to refinements in the concept and implementation that are described in this paper. The paper also outlines plans for field evaluations. SMS will be evaluated operationally at Memphis International Airport, first in FedEx's ramp tower beginning in August, 2002 and, subsequently, in the air traffic control tower (ATCT) in 2003.

Introduction

Departure taxi delay is the largest of all aviation movement delays and results in the largest addition to direct operating cost. The average taxi-out delay in minutes-per-flight is approximately twice the airborne delay. Although aircraft burn fuel roughly five times faster when airborne, crew and equipment costs make the spend-rate of taxiing aircraft about two-thirds that of airborne aircraft. Consequently, the cost of taxi-out delay exceeds that of airborne delay by about one-third. On average, taxi-out delay is three times larger than taxi-in delay [1]. The delays that occur on the airport surface may result either from restrictions on the surface (e.g., airport surface congestion and runway capacity limitations) or from restrictions due to limited capacity of other downstream elements of the National Airspace System (NAS). SMS provides information and support for the management and reduction of both types of airport surface delays.

The Advanced Air Transportation Technologies (AATT) Project at NASA Ames Research Center, in cooperation with the FAA, is studying automation for aiding airport surface traffic management. The Surface Management System is a decision support tool that provides information and advisories to help traffic managers, controllers and air carriers collaboratively manage the movements of aircraft on the surface of busy airports, thereby improving capacity, efficiency, and flexibility. This paper describes SMS, which is an element of the FAA's Free Flight Phase 2 (FFP2) program. The paper refines and adds detail to the SMS description provided in [2], based on what has been learned through recent development activities, including two real-time, controller-in-the-loop simulations [3]. Note that this SMS concept addresses many of the recommendations for the future of the airport surface cited in the RTCA Free Flight Steering Committee's NAS Concept of Operations [4].

Detailed information about the future departure demand at an airport is not currently available. SMS provides operational specialists at ATC facilities and air carriers with accurate predictions of the future departure and arrival situation. Near-term predictions of departure sequences, times, queues, and delays for runways or other resources support tactical control of surface operations, while longer time-horizon, aggregate forecasts (i.e., total demand for a resource per interval of time) support strategic surface planning. The resulting shared awareness of the current and future arrival and departure situation enables improved decision making and collaboration among those users. Note that this is a similar capability for departures as the predicted arrival demand and expected delay information provided by the Center-TRACON Automation System (CTAS) Traffic Management Advisor (TMA). Furthermore, SMS uses its ability to predict how future demand will play out on the surface to evaluate the effect of various traffic management decisions in advance of implementing them, to plan and advise surface operations.

Concept of Use

SMS users may not have the necessary information or time to plan beyond immediate aircraft movements, especially during busy periods. SMS has three fundamental capabilities: 1) the ability to predict the movement of aircraft on the airport surface and in the surrounding terminal area (i.e., what will happen assuming current traffic management initiatives), 2) the ability to use this prediction engine to plan surface operations (i.e., what would happen assuming various other traffic management initiatives), and 3) the ability to disseminate this information and provide appropriate advisories to a variety of users.

By providing information about the future surface situation that is not currently available, SMS allows the ATCT, Terminal Radar Approach Control (TRACON), Air Route Traffic Control Center (ARTCC), and air carriers to coordinate traffic management decisions based on a common situation awareness. SMS-provided information is expected to be most helpful during irregular operations, when knowledge of daily schedules gained through experience cannot be used to predict the timing of future demand. To predict the near-term state of traffic on the surface, SMS uses real-time surface surveillance information that includes aircraft identity, from ASDE-X or another similarly capable system, and a surface trajectory synthesis algorithm that accurately predicts the movement of aircraft on the airport surface. The surface trajectory synthesis algorithm is functionally similar to that used by CTAS to predict the trajectories of airborne aircraft. To predict departure times further in advance (i.e., prior to aircraft pushback), SMS uses airline-provided information about when each aircraft will want to push back in conjunction with the trajectory synthesis algorithm.

The ability to predict the future surface situation enables SMS to aid users by advising how to manage some aspects of surface operations to best achieve strategic goals. SMS's planning tools attempt to increase airport throughput (i.e., peak capacity rate), increase the efficiency of surface operations (i.e., minimize the cost of unavoidable delays and their environmental impact), and improve user flexibility (i.e., minimize the impact of delays on air carrier business objectives), without increasing user workload. SMS continually updates its advisories to react to the current situation and controller actions and is collaborative between the ATCT and the air carriers.

Table 1. SMS products can be grouped into three distinct components to support distinct user groups.

Traffic Management tool	Controller tool	NAS Information tool
• ATCT TMC • TRACON TMC • ARTCC TMC • Ramp tower supervisor • Air carrier AOC	• ATCT Local and Ground controllers • Ramp tower controllers	• Air Traffic Control System Command Center (ATCSCC) • Air carriers (AOC and ramp tower)

These fundamental capabilities allow SMS to provide information and advisories about the future situation on the surface that are customized to the needs of each user. Note that any of the SMS capabilities can be turned off, as appropriate for a particular site or individual user. The following sections describe the SMS capabilities provided to each user. SMS could be deployed as three separate tools, listed in Table 1: 1) a traffic management tool used by the ATCT, TRACON, and ARTCC TMCs as well as ramp tower supervisors and air carrier AOCs, 2) a controller tool for the ATCT Local and Ground controllers as well as ramp tower controllers, and 3) a tool to provide data to increase the predictability of the National Airspace System (NAS) and, thereby, support traffic flow management (TFM). This paper describes the SMS capabilities that will be tested during field evaluations. Subsequent development efforts will extend SMS to include additional capabilities and interoperate with arrival, departure, and other surface traffic management decision support tools. This paper does not enumerate the possible extensions that might be pursued subsequently.

ATCT Traffic Management Coordinator

The traffic management tool component of SMS is used by Traffic Management Coordinators (TMCs) in the ATCT, TRACON, and ARTCC, as well as ramp tower supervisors and air carrier AOCs.

Departure Scenario Selection

SMS affects departure runway assignments through three mechanisms: 1) supporting the selection of the departure scenario and the schedule for changing the scenario, 2) supporting runway assignments for specific flights that are exceptions to the active departure scenario, and 3) supporting flight plan changes that will adjust runway assignments. This section discusses the first mechanism. The second mechanism is discussed in the section on Ground controller products; the third mechanism is discussed in the section on SMS capabilities for the air carrier's AOC.

Current procedures assign departures to a runway according to a one-to-one mapping from departure fixes to departure runways. The purpose of these runway assignment rules is to assure that the airborne trajectories of aircraft that take off from different runways do not cross. The different mappings of departure fixes to departure runways are referred to as *departure scenarios*. For example, Figure 1 shows the departure scenario Dallas–Fort Worth airport (DFW) typically uses during an eastbound push in south flow operations. The ATCT selects the departure scenario to balance the demand on each of multiple departure runways.

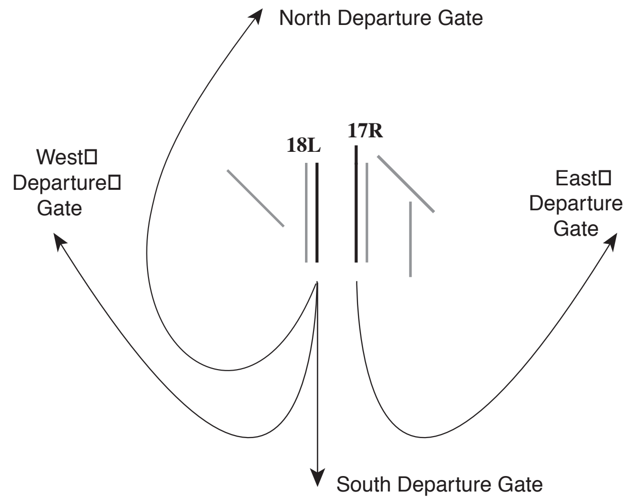

Figure 1. DFW departure scenario for an eastbound push during south flow operations.

SMS supports the ATCT TMC's selection of the departure scenario first by providing information about the unconstrained demand for each of the departure fixes/gates as a function of time. The *unconstrained* traffic count is the number of aircraft that want to use the resource during each time interval. In contrast, the *constrained* (or scheduled) traffic count is the number of aircraft that will use the resource during a time interval, accounting for required separation and controller workload limitations. During normal operations, controllers know approximately when each flight departs from experience. However, during irregular operations, flights will not depart at their typical times. Although controllers can scan the Flight Progress Strips (FPSs) for all of the proposed flights to estimate the demand for each departure fix, the time at which each flight will want to depart is not currently known reliably, since air carrier decisions to adjust their schedules may not be reflected in the times printed on the FPSs. Figure 2 shows an SMS display of the unconstrained future departure demand at DFW sorted by the four departure gates. The horizontal axis shows a one hour time horizon, starting with the current time. The number of aircraft is determined by counting the planned departures in a 15-minute window starting at that time. The data shown was taken from a traffic scenario used during the second controller-in-the-loop simulation of SMS.

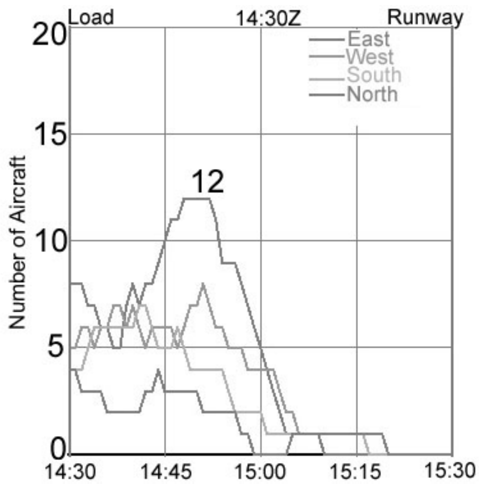

Figure 2. SMS display of the unconstrained future departure demand sorted by departure gate.

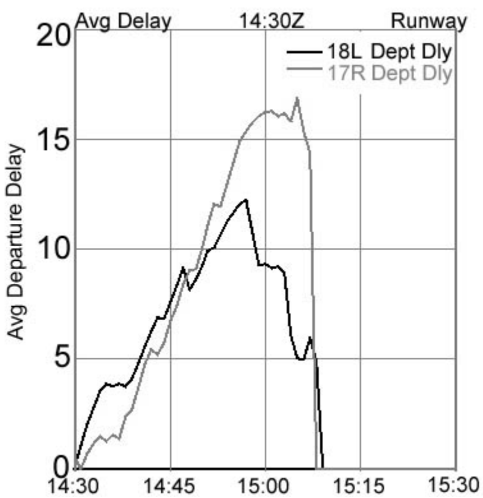

Figure 3. SMS load graph of the predicted departure delays at each runway.

SMS also predicts the queues and delays that will exist at each runway as a result of the demand. Figure 3 shows an SMS load graph of the predicted average delay that will be experienced at each runway, assuming the *East Push* departure scenario. SMS can calculate multiple predictions for alternative traffic management decisions, to provide a “what if” capability. For example, SMS can display graphs like Figure 3 for several available departure scenarios to aid the TMC in selecting the most efficient departure scenario and when to change the scenario. As an alternative to average delay information, SMS can display the predicted lengths of the departure queues at each runway (Figure 4)

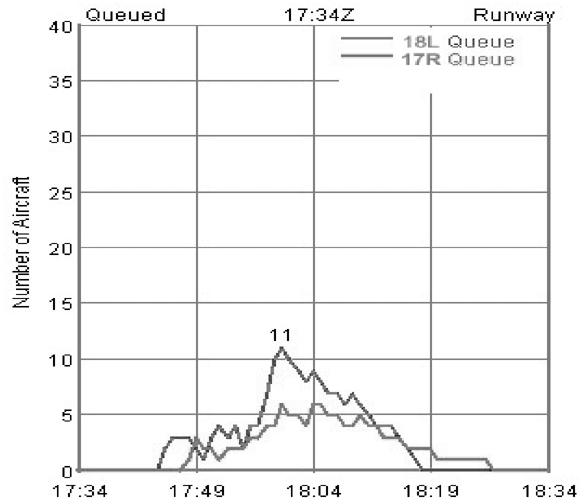

Figure 4. SMS display of the departure queue length at each runway.

In addition to aggregate forecasts (i.e., total number of aircraft in a period of time, without identifying individual flights), SMS predicts the movement of individual aircraft. Figure 5 is a pair of SMS timelines that show the predicted departure and arrivals times over the next hour, also assuming a particular departure scenario. The timeline is referenced to runways 17C and 17R at DFW during a simulation of SMS[1]. Color is used to distinguish the departure gate to which a flight is filed, or otherwise categorize the flights. TMCs typically use the density of flights and the color-coding to obtain trend information.

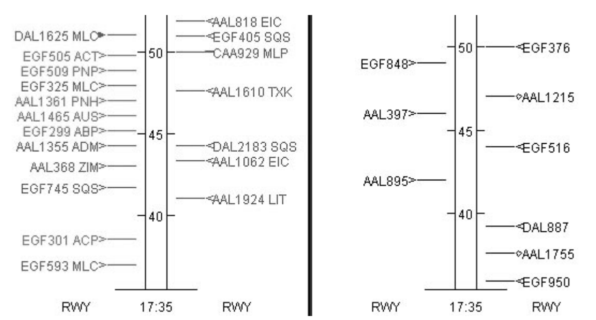

Figure 5. SMS timeline display showing predicted operations at each runway.

[1] During the SMS simulations in FFC, only the east half of DFW was simulated. Consequently, both runways 17R and 17C were used for departures.

TRACON and ARTCC TMCs

Tradeoff of Arrival and Departure Rates

At airports where arrival and departure capacities are interdependent, due to interactions between the two types of operations, arrival and departure management must be interoperable. SMS provides the TMCs in the ATCT, TRACON, and ARTCC with a common picture of both the unconstrained future arrival and departure demands as well as the constrained traffic counts and delays that are predicted to result after necessary separations are applied. This shared awareness allows the TMCs to coordinate traffic management decisions, for example trading off the arrival and departure capacities in a way that is appropriate for the competing demands, resulting in more efficient use of the limited resources. Additionally, this information may support adjusting the arrival and departure rates more dynamically to track the time-varying demands. Figure 6 displays the unconstrained future arrival and departure demands. SMS also displays the arrival and departure delays that will result under a set of traffic management assumptions.

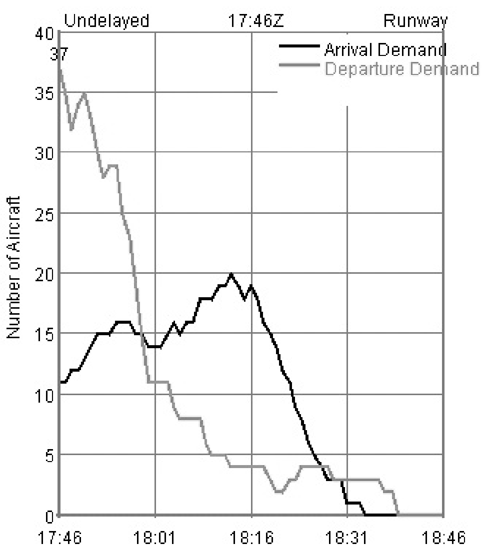

Figure 6. SMS display of unconstrained arrival and departure demands.

SMS also offers a trial-planning capability, in which SMS predicts the arrival and departure delays that would result from a traffic management decision that is being considered. Before committing to a possible traffic management decision, the TMC can see what the timelines and the load graph of arrival and departure delays would look like. Finally, SMS can advise a schedule of coordinated arrival and departure capacities that best match the time-varying demands for the two types of operations.

Coordination of Arrival and Departure Runway Use

SMS provides information about current and predicted departure queues in the TRACON Traffic Management Unit (TMU) to enable better coordination of the use of runways for arrivals and departures, without explicit communication between the ATCT and TRACON TMCs. This display shows when a departure queue does or will exist at a runway, without the ATCT needing to call, to help the TRACON TMC make decisions about moving arrivals to a different runway or slowing the arrivals.

APREQ Release Times

SMS also helps manage Approval Request (APREQ) flights. Currently, the ATCT (often the Ground controller when the aircraft calls for pushback or reaches the hand-off spot) calls the ARTCC TMU for a release time. The ATCT tells the ARTCC TMC the earliest time the aircraft could be at the runway, and the TMC estimates at what time the flight should takeoff to fit into an appropriate gap in the traffic stream into which the flight must be merged. SMS supports this process, first, by predicting the earliest time at which the flight would be able to reach the departure runway, accounting for surface traffic. SMS provides a table of the earliest possible departure time for each APREQ flight, accounting for surface traffic, directly to the ARTCC TMC. When convenient, rather than when the ATCT calls, the ARTCC TMC can plan a release time, enter it into SMS, and SMS will relay the release time to the ATCT without the ATCT having to call. If a flight's release time is entered into SMS, either by the ARTCC TMC or by the ATCT if the current voice communication with the ARTCC TMC is maintained, SMS will help the Ground and Local controllers meet this restriction, similar to the way SMS supports meeting Expected Departure Clearance Times (EDCTs) and hold-over limits during deicing.

Air Carrier Ramp Tower

Ground Resource Planning

SMS provides estimates of when each arrival aircraft will reach its spot and parking gate, using timelines and tables. SMS uses parking gate information to estimate the taxi time for each arrival. Better gate arrival time predictions improve air carrier decision making about gate and ground resource management, as well as whether or not to hold departures to allow late arrivals to make connections. Where CTAS is available, SMS will use the CTAS estimates of touchdown time; otherwise, SMS predicts landing times itself.

Departure Planning

SMS helps the ramp supervisor and controllers manage pushback times. SMS provides information about the current downstream restrictions (e.g., Miles-in-Trail (MIT)) that affect each flight and the delays that will be experienced at each departure fix or runway. SMS plots how the departure queue length will evolve 1) if no additional aircraft pushback and 2) assuming aircraft continue to pushback at their scheduled times. The ramp controller can use this information, for example, to hold pushing back a flight that will be delayed at its runway to allow other flights out of the ramp first. As long as a queue exists at the runway, no departure capacity is wasted. Therefore, the ramp could hold other departures so that when a late departure is ready it will wait behind a shorter queue.

Arrival / Departure Coordination

Predictions of when arrivals will reach their gates will help ramp controllers make decisions about gate availability. For example, the ramp controller will know how long a departure can wait to push back before an arrival will be delayed. If an arrival is expected to reach a gate before a departure occupying that gate will be ready to push back, the ramp controller can reassign the arrival to a different gate or request that the ATCT hold the arrival out until the gate is available. ATCT Ground controllers desire to know earlier in an arrival’s taxi whether the ramp tower will accept the aircraft or ask the ATCT to keep the aircraft. SMS allows the ramp tower to enter when an arrival’s gate is unavailable, which is relayed to the ATCT.

At some airports (e.g., Atlanta’s Hartsfield International airport) a narrow alley separates terminal buildings, creating the opportunity for congestion between arrivals and departures. If an arrival needs to park at a gate past where a departure has pushed back, the arrival must not enter the alley before the departure has exited. SMS-provided information about when arrivals will reach spots will help the ramp tower make decisions about holding a push back to avoid gridlock (i.e., the departure needing to be tugged back up to the gate) or requesting the ATCT hold the arrival to allow a higher priority departure to get out first.

Handle Departure Time Restrictions

SMS aids the ramp tower in managing flights to meet departure time restrictions. During de-icing operations, SMS allows the ramp controller to enter the maximum hold-over time for each aircraft, which is automatically communicated to the ATCT so that the controllers know by when aircraft must depart to avoid needing to be de-iced again. Furthermore, SMS information helps the ramp tower manage the length of the queues at the runways and the de-icing stations. To help the ramp tower determine when to start de-icing a flight, SMS estimates the departure delay that the flight will incur after de-icing. SMS predicts the queue lengths and delays both at the runway and the de-icing operation.

Sequence Departures

SMS allows the ramp supervisor to enter the relative priority of each departure. SMS can display this information to the Ground and Local controllers, to be included in their decision making as appropriate.

At some airports, such as DFW, the taxiway geometry allows the ATCT to construct efficient departure sequences after aircraft enter the active movement area. However, the taxiway configuration at other airports limits the ATCT’s ability to sequence departures once aircraft have pushed back from their gates or entered the active movement area. In this case, SMS will provide departure sequence advisories to the ramp tower controllers, that avoids consecutive flights to the same fix, for example, so that the ATCT can construct a departure sequence that efficiently uses the runways.

Airline Operations Center (AOC)

Flight Plan Changes

SMS considers whether changing a flight plan for a particular flight would be beneficial to avoid delays at a runway or departure fix, depending on which is the constrained resource. By changing the departure fix, a flight plan change can result in a different departure runway being used without violating the rules of the active departure scenario. The departure fix may also be changed where the same runway would be used to avoid either high demand for that fix or downstream restrictions (e.g., MIT) on that fix. SMS considers the impact on taxi distance and flight time when calculating the benefit of a flight plan amendment. Currently, the ATCT will occasionally initiate flight plan changes. At DFW, for example, this is typically done by the Clearance Delivery (CD) controller when issuing the pre-departure clearance. However, it may be done after the aircraft has pushed back and is waiting at a spot, in which case the Ground controller instructs the pilot to contact CD for a new route, and a new flight strip is generated in the tower. SMS automates the search for candidate flights and provides supporting information.

Due to its affect on fuel requirements or business objectives, the flight's dispatcher/AOC may need to approve a flight plan change. In accordance with the existing Coded Departure Route (CDR) program, which facilitates the communication and coordination of alternate departure routes, the flight's dispatcher can evaluate CDRs (possibly recommended by SMS) and confirm that the aircraft has the appropriate fuel. The dispatcher would do this either when initially filing the flight plan or at some later time, but before the pilot contacts the CD controller. The dispatcher enters the approved CDRs into SMS and informs the pilot which CDRs may be accepted; SMS indicates to the ATCT which CDRs are available for that flight.

The purpose of changing the departure runway for a particular flight could be either to help balance the departure runways or to help that particular high-priority flight takeoff earlier. Either the ATCT or the AOC can initiate use of a CDR. SMS provides information about the predicted delays for each departure fix and runway to enable the ATCT (TMC or CD controller) or AOC (dispatcher or ATC coordinator) to evaluate which flights to reroute. The AOC would initiate a flight plan change either by calling the TMC or instructing the pilot to make the request to the CD controller. In addition, SMS can advise the ATCT TMC which flights should be rerouted and which of the available CDRs for those flights should be selected.

Air Traffic Control System Command Center

Data to the Enhanced Traffic Management System (ETMS)

The NAS information tool component of SMS provides data to ETMS to support the ATCSCC and to be further disseminated to NAS users. There currently exists a large amount of uncertainty in the TFM system regarding the time at which flights will depart from their origin airport. This uncertainty accounts for a significant portion of the error in the ETMS Sector Monitor Alert capability and in the Flight Schedule Monitor (FSM) tool. Other FAA projects are currently studying using real-time surveillance data to detect pushback and takeoff events, and provide these surveillance-derived OUT and OFF times to ETMS. In addition, the TFM system needs accurate *predictions* of when each flight will takeoff. Pushback detection can be used to improve takeoff time prediction, although using historical averages of taxi time introduces substantial uncertainty. By modeling the movement of the traffic actually on the surface at the time and, thereby, providing accurate taxi time estimates, SMS can further improve takeoff time predictions. SMS-predicted takeoff times are communicated back to the ETMS system for use in Monitor Alert calculations and in the FSM tool, transparently improving all of the predictions and products that are based on predicted takeoff time. Although some interface protocols already exist to allow airlines to submit updated predictions of a flight's takeoff time, some modifications in the ETMS system may be required to accept the SMS data.

ATCT Ground Controller

Flight-specific Information

SMS uses a map display to provide a variety of flight-specific information to the Ground and Local controllers. SMS research has shown that the Ground and Local controllers have a strong preference for all necessary information being available from a single display. Therefore, eventually any information that SMS provides to the Local and Ground controllers will likely need to be incorporated into the ASDE-X display or the STARS tower display. Since this integration is beyond the scope of the current NASA project, the SMS research is using a separate map display to evaluate what information content is useful. This SMS map display resembles the ASDE-X display, but does not fully conform to the FAA’s Visual Specification for Airport Surface Applications (VSASA) [5]. Figure 7 shows the map display covering the east half of DFW.

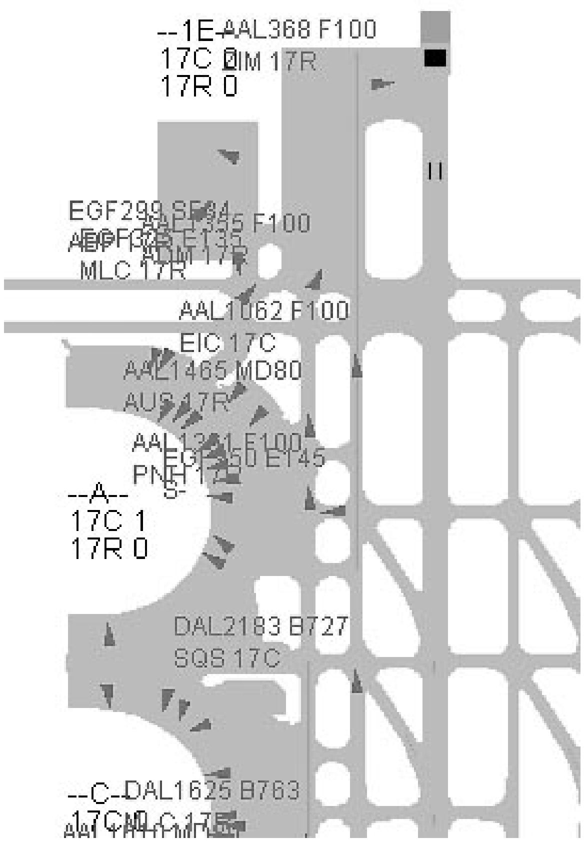

Figure 7. SMS map display.

Gate / Spot Information

Ground controllers use knowledge of an arrival’s parking gate (or the hand-off *spot* at which the aircraft transitions from ATCT to ramp tower control) to plan a taxi route for the aircraft. In addition, TRACON Arrival controllers sometimes use this information for arrival runway assignments. SMS conveys this information with less workload than is currently required. Currently, the ramp tower (or the air carrier’s *station* at airports where the air carrier does not operate a ramp tower) informs pilots of their parking gate or spot when they call “in range.” At DFW, for example, the pilot then relays this information to the Ground controller at initial contact. During night operations at Memphis International airport (MEM), the pilot relays the ramp entry spot to the TRACON Arrival controller, who enters it into the ARTS scratch pad. The Ground controller then copies it from the Digital Bright Radar Indicator Equipment (DBRITE – the repeater of the TRACON radar display located in the ATCT). SMS receives this information directly from the air carrier and relays it to the ATCT earlier and with less radio communication. The gate/spot information appears in the second line of the arrivals data block on the map display.

At DFW, knowledge of the arrival spot also helps the arrival and departure Ground controllers coordinate, without explicit communication, whether a departure must hold at a spot for an arrival to taxi across in front of the departure, or may proceed across the spot because the arrival will turn into a spot before reaching the departure.

If the parking gate assigned to an arrival is not yet available, the ramp tower can enter into SMS the earliest time the parking gate will become available, to indicate how long the ATCT must delay the aircraft on the surface before it may enter the ramp. SMS will relay this information to the Ground and Local controllers via the map display, using either an entry in the data block or coloring the aircraft icon. The same mechanism can be used to indicate when an arrival or group of arrivals must be delayed because the ramp is not available (i.e., an alley needs to be kept clear to allow a priority departure to exit the ramp first).

Runway Assignment Advisories

SMS displays the predicted departure runway assignment for each departure aircraft, based on the active departure scenario and the flight’s departure fix, in the second line of the map display data block (Figure 8). The Local, Ground, or TMC can change the SMS-planned runway, which will be reflected in the data block and all other SMS displays. In addition, if SMS recognizes, based on surface surveillance, that the aircraft is being taxied to a different runway, SMS will change the predicted departure runway for the flight.

Figure 8. Data block for departure aircraft.

Ground controllers make exceptions to the departure scenario when assigning runways both to balance runways and, during less busy periods, to assign aircraft to the runway closest to their parking gate to reduce taxi distance. SMS can advise exceptions to the departure scenario; this capability, like any others, can be turned on or off. SMS's flight-specific runway advisory function searches to determine whether a small number of departure runway assignments that are exceptions to the departure scenario could provide a significant reduction in total departure delay. Since these runway assignments would violate the active departure scenario, the search for beneficial alternate runway assignments is constrained by the requirement that the suggested runway assignments cannot cause airborne conflicts. Airborne departure conflicts would represent a safety concern and create high controller workload. For example, in the *South Flow East Push* departure scenario at DFW, a departure from Runway 18L could fly to the EIC (Belcher) departure fix (the southern most fix in the east departure gate) by remaining south of the 17R departures. This flight path would avoid conflicts with the eastbound departures from 17R, as long as two flights bound for EIC do not depart such that both arrive at the fix at the same time.

These runway assignment advisories can either be displayed directly to the Ground controller, who can use or ignore the advisory, or first displayed to the TMC who can filter or approve the advisory before it is presented to the Ground controller. At airports where the runway assignment decision must be made prior to aircraft pushback which is controlled by the ramp tower, the TMC must approve exceptions in advance. SMS can be used to communicate the runway assignment for each flight to the ramp tower.

SMS considers both the longer taxi distance and additional flight time when calculating the benefit of a runway assignment. SMS suggests changing the departure runway for a particular flight to reduce the overall departure delays. However, SMS currently constrains the search to flights that would not incur a longer individual delay.

Note that controllers currently identify runway assignment exceptions manually when workload permits. Although the aircraft will be flying to the same departure fix as is in its flight plan, since the aircraft will be departing off a different runway, the ATCT must coordinate with the affected Departure controllers to assure that airborne separation will be maintainable with acceptable workload. The aircraft will be displayed on the radar scope of the Departure controller assigned to the filed departure fix, but will be coming off a different runway than the other aircraft handled by that controller. This is easiest done at the beginning of a departure push, before the airspace gets busy. By automating the search for feasible and beneficial runway assignments that are exceptions to the current departure scenario, SMS may allow more frequent use of the technique during busy periods.

ATCT Local Controller

Meeting Departure Time Restrictions

SMS displays information in the map display data block to help controllers meet EDCTs and APREQ release times. SMS receives EDCT constraints from ETMS; release times for flights under APREQ procedures will need to be entered into SMS. SMS displays the takeoff time restriction in the data block on the Ground and Local controllers' map displays (e.g., "EDCT 1807," indicating the flight must takeoff between 1802 and 1812).

If SMS predicts that a flight will takeoff earlier than the earliest allowed time, the field in the data block will alternately display the departure restriction and the number of minutes the flight needs to be delayed (e.g., "HOLD 5"). If the predicted takeoff time is after the latest allowed departure time, the data block on the map will alternately display the number of minutes the flight must be expedited (e.g., "EXP 6"). In addition, SMS can notify the ATCT TMC if a flight is predicted to require special attention in order to meet a departure time constraint.

During de-icing operations, the ramp tower can enter the maximum hold-over time before a flight will need to be de-iced again. SMS displays the latest departure time for each flight with a hold-over limit in the data block on the Ground and Local controllers' map displays (e.g., "ICE 1537"). If SMS predicts the flight needs to be expedited to avoid needing to return to the de-icing pad, SMS provides an expedite advisory, similar to that for EDCT and APREQ departure windows. The potential for airlines to abuse this capability to receive departure preference relative to other airlines, for example by entering false hold-over limits, de-icing too many aircraft in a period of time, or using de-icing fluid with shorter hold-over times, will be studied.

Departure Sequence

SMS plans and recommends to the Ground and Local controllers a departure sequence for each runway that maximizes runway throughput subject to wake vortex and downstream traffic management restrictions (e.g., MIT and EDCTs). An additional objective of departure sequencing is to incorporate air carrier priorities to enhance user flexibility without compromising fairness or throughput. SMS provides sequence advisories to the Ground controller to aid in constructing an efficient sequence that incorporates user priority when feasible (e.g., does not reduce airport efficiency or increase controller workload). During simulations, controllers indicated that they are interested in the next aircraft and the one after that, but do not need to know the sequence beyond that. In contrast, the TMC prefers to see the sequence over the next 15 minutes to allow an opportunity to re-order flights. An appropriate user interface through which to provide sequence advisories to the Ground controller has not yet been determined. Highlighting of the data blocks on the map display, sequence numbers in the data blocks, and a sequence list in an empty area on the map display are being studied. The Local controller will continue to receive the departure sequence from the order in which the Ground controller arranges the FPSs in the Local controller's strip bays, as is currently done. The TMC will continue to influence the sequence as is currently done by interacting with the Ground and Local controllers.

System Architecture

Figure 9 shows the system architecture for SMS. SMS displays will present information and advisories to the Local and Ground controllers as well as the TMC in the ATCT, to the TMCs in the TRACON and ARTCC, and to the air carrier's ramp towers and AOCs. In addition, SMS data will be provided to ETMS to improve traffic flow management products that use predictions of takeoff times.

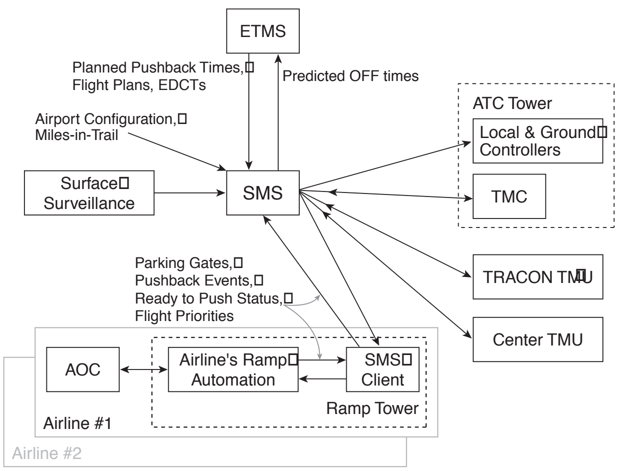

Figure 9. SMS System Architecture.

SMS uses real-time location and identity information about aircraft on the airport surface, although some SMS capabilities will function without this input. SMS will receive this information from the ASDE-X system, currently being developed by the FAA. Note that to provide many of the planned capabilities, SMS needs surveillance of the ramp areas, which the FAA has not currently specified as a requirement in the ASDE-X program, as well as the active movement area. At Memphis International airport, the SMS field test location, SMS receives surface surveillance information from the FAA SafeFlight 21's ASDE-X prototype. The surveillance system at Memphis does provide coverage of the ramp areas. SMS also gets limited airborne surveillance information from the SafeFlight 21 system, which it will use along with ETMS data in the prediction of landing times for the arrivals.

SMS receives flight plan information, surveillance information for arrivals outside the terminal area, and the air carrier's updated planned departure times for each flight from ETMS. To correctly model inter-departure times, SMS must know what downstream restrictions are in effect. ETMS also provides EDCTs for aircraft affected by ground holds. The current airport configuration, planned configuration changes, MIT restrictions, and APREQ times must be manually entered.

Initially, SMS information will be displayed on separate displays in the air carrier facilities. Eventually, the SMS information will be provided via a standard interface, so that the air carriers can integrate it into their automation systems. During field testing in Memphis, SMS will connect to FedEx's Ramp Management Automation System (RMAS) to receive parking gate information. SMS needs to know at what gate each arrival will park to predict taxi-in times as well as surface conflicts between arrivals and departures. SMS also receives flight status information (i.e., ready to push and pushed back) from RMAS to compensate for flights that do not appear in the surface surveillance data. Air carrier priorities are entered manually by the ramp tower or AOC. Eventually, the air carriers will provide this data through either ETMS or the standardized interface across which they receive SMS data. This approach avoids the need to interface separately to every air carrier's ramp tower automation system.

Development Approach

NASA is committed to developing the initial version of SMS described in this paper to Technology Readiness Level (TRL) 6 in time for transfer to the FAA's FFP2 program. The Free Flight Program Office is supporting the development of SMS and will continue to work with NASA throughout the project to transfer SMS technology to the FAA.

Human factors research, integral to all aspects of SMS development and testing, is being conducted to determine system requirements – what functionalities are appropriate for each user, how information should be displayed so that it is suited to the tasks being supported, and what the system performance is required for user acceptance. SMS is being designed so that there are no usability concerns for accessing or interpreting information, and so that using the information does not adversely increase workload. Experience from developing CTAS has shown that involving the eventual users throughout the development process significantly benefits the quality, operational applicability, and usefulness of the final product. Therefore, the FAA and NASA have formed an SMS user cadre, consisting of ATCT controllers, traffic managers, and air carrier representatives, to provide feedback on the SMS concept, performance, and interfaces, throughout development. Two real-time, controller-in-the-loop simulations have been conducted using the Future Flight Central (FFC) ATCT simulation facility at NASA Ames Research Center [3]. Results from these simulations, held in September, 2001 and January, 2002, are being used to refine the functionalities and user interfaces. The simulations modeled DFW airport; SMS has already been adapted to four airports as part of the development and benefits assessment work.

Additional user feedback to continue refining SMS will be obtained through several operational evaluations at Memphis International Airport. SMS field tests will be conducted in Memphis to take advantage of the FAA's SafeFlight 21 experience and infrastructure at the airport. Memphis airport exhibits surface and departure characteristics that are common to many airports. For example, Memphis airport experiences significant departure queues and unbalanced departure runways during some departure pushes, and the airfield layout creates opportunities for surface congestion and runway crossing delays. The primary air carriers at Memphis, FedEx and Northwest Airlines, are supporting NASA's SMS development efforts.

To gain additional experience with its performance and reduce risk associated with subsequent demonstrations, SMS will be deployed first to the FedEx ramp tower in August, 2002. SMS may also be evaluated in the Northwest Airlines ramp tower. In the fall of 2002, SMS will be demonstrated in FedEx's Global Operations Center (GOC) to study how SMS information supports more strategic air carrier decision making. SMS data will also be provided to ETMS in the fall of 2002 to evaluate the benefit of SMS-predicted takeoff times. The ATCT TMC will first evaluate SMS in shadow-mode, in January, 2003. Shadow-mode testing uses real-time data sources but allows the user to exercise SMS in a non-operational environment, to verify that it is ready to be used operationally. An operational demonstration is planned for later that winter. Similarly, the TRACON and ARTCC TMCs will test SMS in shadow-mode before beginning to use it operationally. Shadow-mode testing by the Local and Ground controllers is planned for April, 2003 in preparation for an operational demonstration in June, 2003. Whether NASA’s prototype version of SMS will remain operating in each of these facilities or removed at the conclusion of the demonstration will be determined by the FAA.

Throughout the development of SMS, NASA has carefully evaluated the trade-off between the benefit of SMS capabilities and the complexity of the algorithms and adaptation data required to support those capabilities. Significant SMS deployment issues will be avoided by using the most simple algorithmic approach that meets the requirements. SMS could be deployed as three somewhat separate tools: 1) a traffic management tool used by the TMCs (ATCT, TRACON, and ARTCC) and air carriers, 2) a controller tool for the Local and Ground controllers and ramp tower controllers, and 3) a system that provides improved data to support national traffic flow management (TFM).

As the foundation for subsequent surface automation capabilities, this initial SMS development is establishing a software design and hardware architecture that is open, modular, flexible, and extensible, so that new functionalities and additional input sources may be added in the future. The design will allow for interoperability with CTAS as well as other decision support tools, and will be extendable to other airports.

Conclusions

The goal of this project is to develop and field test a proof-of-concept SMS to determine the appropriate functions and interfaces and to validate predicted benefits. One goal is that the SMS prototype could be directly duplicated at other airports. However, based on lessons learned, the FAA may determine that some re-design of the implementation is required before SMS can be broadly deployed. For example, the human factors need to minimize the number of displays in front of ATCT controllers may motivate sharing of displays rather than installing dedicated SMS displays. Consequently, SMS’s eventual deployment configuration may incorporate SMS data elements into the displays associated with other systems (e.g., ASDE-X or the STARS ATCT display). In addition, to improve maintainability, the SMS software algorithms could be hosted as part of some other automation system (e.g., ETMS). Integration of SMS with these other systems is beyond the technical scope of the current task and the time available.

This initial SMS development will not explore every opportunity for surface management automation. In particular, opportunities exist for automation tools to interact with SMS to provide additional benefits. NASA is currently considering extensions to the initial SMS described in this paper. Subsequent research and development will add these additional capabilities to SMS in phases, and transition them to the FAA as appropriate

This paper describes the SMS concept at this point in SMS development. As work continues, additional detail will be identified, and elements of the concept may change, especially as a result of user involvement.

References

[1] Welch, J., S. Bussolari, and S. Atkins, 2001, “Using Surface Surveillance to Help Reduce Taxi Delays,” *AIAA Guidance, Navigation, and Control Conference*, Montreal, Canada.

[2] Atkins, S. and C. Brinton, 2002, “Concept Description and Development Plan for the Surface Management System,” *The Journal of Air Traffic Control*, Vol. 44, No. 1.

[3] Walton, D., S. Atkins, and C. Quinn, 2002, " Human Factors Lessons Learned from the Second Surface Management System Simulation," AIAA Aviation Technology Integration and Operations Conference, Los Angeles, CA.

[4] RTCA Free Flight Steering Committee, “National Airspace System Concept of Operations,” RTCA, Inc., Washington, DC, December 13, 2000.

[5] FAA, May 28, 2001, “Visual Specification for Airport Surface Applications (VSASA),” FAA-E-2943, Version 1.1.